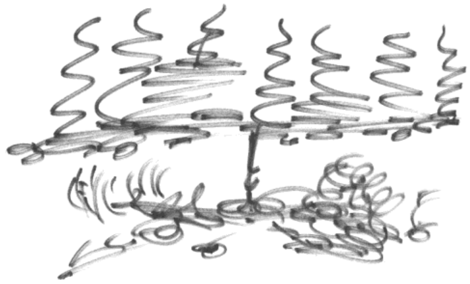

A SELECTION OF FISH CONSUMPTION RATES FOR USE IN SETTING WATER QUALITY STANDARDS

DRAFT

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EXECUTIVE SUMMARY

Purpose.

This report presents fish consumption rates for various populations of fish consumers in Washington State and for the population of the USA. The USA population is considered as a potential surrogate for the general population of Washington, which has not had a published, population-based fish consumption survey. Six populations are considered:

United States population
Tulalip Tribes
Squaxin Island Tribe
Suquamish Tribe
Columbia River Tribes: Nez Perce, Umatilla, Warm Springs and Yakima Tribes
Asian and Pacific Islanders residing in King County

Methods.

The data are all derived from sample surveys. The reported rates (in grams/day—g/day) are limited to fish consumers only. Consumers are defined in terms of consumption of the species group considered. Consumption rates are presented, when available, for all species (fish and shellfish combined), for non-anadromous species, for shellfish, and for finfish. These categories of species are also, when possible, broken down into consumption rates for fish obtained from all sources, as well as for fish harvested from Puget Sound, from the Columbia River, or just “harvested.”

In general the mean, median and 95th percentile of rates are presented for most of the populations and by categories of fish species and source of fish consumed. Other percentiles are presented for some populations.

Data on consumption rates at the level of individual respondents was available only for the USA population (from a national sample survey) and for the Tulalip Tribes. For other populations some of the consumption rates have been previously calculated for consumers only from data at the individual level and reported, and those rates are included here, when available. When not simply transcribed from other reports, the rates have been computed by various methodologies starting from published aggregated rates (means and percentiles). The different surveys and their published reports required different methodologies for estimation of consumption rates for this report. The varying methodologies are only briefly treated in the body of the report, but there are additional details in the appendices. Those who are interested should be able to reproduce the rates presented in this report. Calculation of some rates would require access to raw individual survey data.

For the reader who is interested only in the numeric rates, the appendices can be skipped. The appendices are important for a fuller understanding of various issues in estimation of consumption rates.

Throughout the report the term “fish” refers to both finfish and shellfish combined, unless noted otherwise.

Results.

Some key rates presented in this report appear in Table E-1. The rates span a wide range. The median consumption rates for all species combined and from all sources vary from a low of 12.7 g/day (USA population) to a high of 128.5 g/day (Suquamish Tribe.) These two populations also have the lowest and highest 95th percentile rates, respectively. Among the consumption rates for harvested fish the Native American Tribes have the highest consumption rates (with the highest median of 128.5 g/day occurring from the Suquamish Tribe) and the lowest median rate of 6.5 g/day for the Asian and Pacific Islanders (API), due to their low proportion of harvested fish.

Other rates are presented in tables of the results section and a number of rates are summarized in Appendix 1.

Table E-1. Fish consumption rates (g/day), consumers only, for adults (age 18+), by population, species group and source of fish consumed. USA population, Asian & Pacific Islanders, Columbia River Tribes, Squaxin Island Tribe, Suquamish Tribe, Tulalip Tribes.

Population	Species	Source	N	Mean	Median	95%tile
USA*	all	all	6,465	18.8	12.7	56.6
A & PI	all	all	202	NA	74	286.1
Col. River	all	all	464	63.2	40.5	194
Squaxin Island	all	all	117	83.5	44.4	279.5
Suquamish	all	all	92	NA	128.5	796.9
Tulalip	all	all	73	82.2	44.5	267.6
USA*	all	harvested	NA	NA	NA	NA
Col. River	all	Col. River	464	55.6	35.6	170.7
A & PI	all	harvested	125	NA	6.5	58.8
Squaxin Island	all	Puget Sound	117	52.4	27.8	175.2
Suquamish	all	Puget Sound	91	165.1	57.5	766.7
Tulalip	all	Puget Sound	71	59.5	29.9	237.4

*Rates computed by the NCI method.
NA: not available or data needed for computation not available.

Discussion.

The rates, though diverse, represent a “menu” for use in water quality regulation. The rates are dependent on survey and analysis methodology.

One persistent issue in defining rates for ‘consumers only” is the issue of who is a consumer. These definitions have varied from a definition of a consumer as a person who was consumed fish on either of two days of observation to a definition of everyone as a fish consumer—varying only in amount—to a definition of a consumer as a person who reports eating fish during some defined or undefined past period. These definitions do have an impact on the consumption rates; this report has some discussion on the impact of the “consumer” definition. In using the national data we have been able to screen out those who are self-reported fish non-consumers. All others are regarded as consumers. The “NCI methodology” (Tooze, 2006) has been applied to the national data to obtain the mean and percentiles of fish consumption rates.

The consumption data for individual respondents has not been modified in any way, nor have data been deleted. There is no evidence that any individual consumption rate encountered was impossible. There may be consumption rates that might be considered outliers, but there was no basis for removing or modifying them.

The rates for the USA population may be considered as a surrogate for Washington State general population rates. This is a plausible working assumption, but it is only an assumption. The differences between the two populations should be noted. The national data used for the USA rates covers coastal as well as non-coastal states and includes states with many vs. few fishing opportunities. It may be possible in the future to use a subset of the national data to calculate rates for states that have fishing and harvesting opportunities more similar to those in Washington than the national data provide.

Acknowledgments

We would like to thank the participants in the surveys which supplied data for us to use. Surveys are time-consuming, and openness by the respondents is needed. We thank the many people who have trusted the survey process and have taken the time to share personal information about fish consumption and other aspects of their lives. We also thank the staff members whom we contacted from the Environmental Protection agency (EPA) and the National Cancer Institute (NCI) and the statisticians and scientists who developed the “NCI method.” These people all generously shared their time and experience with us. Finally, we wish to thank the many persons from diverse sectors of the public who offered comments in response to the technical support document that was issued in 2011 by WDOE (WDOE, 2011.) We reviewed all of these comments for issues that might be relevant to the statistical analysis presented in this report. We do feel that we were able to do a better job by having the opportunity to read the many comments.

INTRODUCTION AND BACKGROUND

Purpose of Report:

The purpose of this report is to supply fish consumption rates for adults. The rates are for use in setting water and sediment quality standards. This report does not deal with policy issues nor with economic, social and cultural issues that may play a role in water quality regulation. The purpose of the report is to supply a menu of rates that can be applied to particular adult populations and settings.

Because fish and shellfish live in the water and on or in underwater sediments, they may accumulate toxins that are present in the water and sediments. The toxins are passed on to fish consumers at the time of consumption. Therefore, fish consumption rates are relevant to environmental regulation. Though there may be some problems in using fish consumption rates, their use in determining water quality standards is likely to lead to superior water quality standards than if these rates are ignored.

The work in preparing this report has been commissioned by the Washington Department of Ecology (WDOE).

About this report.

The report follows the IMRD (“imred’) pattern commonly used in scientific journals, with **I**ntroduction, **M**ethods, **R**esults and **D**iscussion sections. The distinction between the methods and results sections here is not strict, because some numerical results need to be presented in the methods section to clarify the use of methods. In order not to burden the reader with too many details, the report also has appendices that contain additional methodologic material. All rates that can be considered as candidates for use in water quality regulation are presented before the appendices.

The use of the term “fish” in this report is intended to cover all finfish and shellfish species combined, unless a specific distinction is made. Unless noted otherwise, fish consumption rates refer to uncooked fish.

Fish consumption surveys

The fish consumption rates supplied in this report are calculated from population surveys. The populations include the general United States population, specified tribal populations, and Asian and Pacific Islander populations living in King County.

Specifically, the fish consumption rates presented in this report are calculated from the surveys of the following six populations (with primary report references noted.)

λUnited States population (NCHS, 2005.)
λTulalip Tribes (Toy, 1996)

λSquaxin Island Tribe (Toy, 1996)
λSuquamish Tribe (The Suquamish Tribe, 2000)
λColumbia River Tribes: Nez Perce, Umatilla, Warm Springs and Yakima Tribes[1] (CRITFC, 1994)
λAsian and Pacific Islanders residing in King County (Sechena, 1999; Sechena, 2003.)

The fish consumption rates derived form these surveys and presented in this report fall into three categories. Two of the categories come from the NHANES national survey; in both of the two NHANES categories the rates are based on two observed days of consumption for each survey respondent.

In the first category of NHANES-derived rates, a fish consumer is defined as a respondent who ate fish on either or both of the two survey days. All other respondents are considered as non-consumers. Mean and percentiles of fish consumption rates have been calculated for these "consumers." This definition would misclassify fish consumers as non-consumers, if the consumers happened not to consume fish on either of the two surveyed days. Thus, this category of fish consumption rates from NHANES is based on a very literal and observation-based definition of "consumer." While this report presents fish consumption rates for this literal definition of "consumer", we do not recommend using this rate for water quality regulation.

In the second category of NHANES-derived rates, some respondents who report themselves as non-consumers of fish (on a separate food frequency questionnaire) have been excluded from the analysis; the remaining, included respondents are considered in this report to be fish consumers—even those who had no observed fish consumption on either of the two dietary recall days. We have applied the "NCI method", developed specifically for this data collection and food consumption scenario, to estimate mean and percentiles of fish consumption.

The third category of fish consumption rates is based on surveys of Native American Tribes in Washington and of the Asian and Pacific Islander population in King County, Washington. These surveys included direct questions on usual fish consumption and other dietary information that provided data for calculation of estimated usual daily fish consumption.

It is important to note that the consumption data are reported from each respondent's memory. Thus, all the surveys are subject to errors of memory and other types of survey reporting errors. Nevertheless, these data should provide a highly informative picture of what fish people eat, both in terms of quantity and types of fish.

<u>Populations, Samples, Statistical Models</u>

[1]The calculated consumption rates and other statistics in the published report represent the combined Columbia River tribes.

This report includes some fish consumption rates estimated directly from data representing consumption by individuals ("individual level data."). Other rates have been estimated using published tabulations of means, medians or other percentiles of rates. Yet other rates have been estimated by fitting a model to data on fish consumption at the individual level. As will be commented on later, one cannot say that one method is specifically superior to the other. Both have merits and problems. Table 1 shows which of the three methodologies have been used to estimate rates for the different populations included in this report. For some of the populations, individual-level data were available for calculation of some rates and their summary statistics, while published tabulations had to be used for calculation of other rates. For example, fish consumption rates for the Squaxin Island Tribe have been calculated and published (Polissar, 2006) for consumers only for fish obtained from any source (harvested, purchased, etc.). However, in order to estimate the Squaxin Island Tribe's consumption rates for fish harvested from Puget Sound, the calculations used the published mean percentages of fish harvested from Puget Sound fro various species groups (Toy, 1996, Table 11.)

Table 1. Source of data used for estimating means, medians or percentiles of fish consumption rates.

Population	Individual level data	Published tabulations	Modeling
United States population	X		X
Tulalip Tribes	X		
Squaxin Island Tribe	X	X	
Suquamish Tribe	X	X	
Columbia River Tribes		X	
Asian and Pacific Islanders	X	X	

We note that we have not used the fish consumption rates presented in an earlier report by EPA (EPA, 2002.) That report used a definition of consumer and the consumption rate associated with a consumer that is quite different than the definition used here[2].

[2] in the EPA 2002 report "consumer" and the rate associated with a consumer was defined as follows (EPA 2002, section 2.2.2.)

"For the purpose of this report, "consumers only" were defined as individuals who ate fish at least once during the 2–day period…."

"If an individual was included in the set of "consumers only," the average daily consumption for that individual was determined using only data from those days when total consumption was greater than zero. For example, if fish was consumed on only one of the two days, the total consumption for the given fish–by–habitat type on that one day was considered the average daily consumption for that individual."

Exposure Factors Handbook

There are a number of reports of fish consumption rates. Prominent among them is the Exposure Factors Handbook (EPA, 2011.) Chapter 10 of this Handbook includes a number of fish consumption rates. Particularly relevant to this report are Tables 10-8, 10-10, 10-12 from Chapter 10. These tables present fish consumption rates derived from a national survey (NHANES)—a survey which is also used here to estimate US national adult consumption rates.

In using fish consumption rates, it is not always possible to exactly match a survey and its derived consumption rates with a specific population. There is simply not a fish consumption survey covering every population of interest in Washington State or in the United States. Thus, those using these fish consumption rates for water quality regulation will need to make a choice among available rates, taking into account the goodness of the match of the survey to the population of interest to them.

Technical Support Document

A great deal of information about fish consumption rates and their use in water and sediment quality regulation can be found in a Technical Support Document (TSD) available from the Washington Department of Ecology (Washington Department of Ecology, 2011.)

Methods And Data

This report has been prepared with consumption rates for “consumers only”. The definition of a fish “consumer” can vary. Our preferred definition of consumer is one whose usual (average) daily intake over an extended period (e.g., one year) is not zero. The rate may be very low or high, but it is not zero. This report uses that definition unless another definition is noted. Some dietary surveys explicitly include questions on how frequently fish are consumed during a specified period, such as a year, or include questions on “usual consumption”. The surveys of Native American Tribes whose rates are reported here use this ‘usual consumption’ approach. Other surveys record fish consumption on specified days. The definition of who is a consumer, thus, may depend on the timeframe. The fish consumption rates for consumers only in the most recent edition of the Exposure Factors Handbook (EPA, 2011) are based on the NHANES two-day dietary recall. The definition of a fish consumer used in the Handbook is a person who consumed fish on at least one of the two days, and the consumption rate attached to that person is the average consumption for the two days[3].

In NHANES (National Health and Nutrition Examination Survey), while there was observation of food consumption (self-reported) for two specified days, there was also

[3] See Section 10.1, Introduction, Page 10-1 of the Exposure Factors Handbook (EPA, 2011.) “The general population studies in this chapter use the term consumer-only intake when referring to the quantity of fish and shellfish consumed by individuals during the survey period. These data are generated by averaging intake across only the individuals in the survey who consumed fish and shellfish.”

some useful information from a food frequency questionnaire (FFQ) embedded in the survey. The FFQ asked the participants how frequently they ate certain types of food over the past 12 months. If a person answered “never” to all fish consumption questions of the FFQ, the answers are probably adequate to distinguish consumers from non-consumers.

Source of fish consumed.

Because the rates are in this report are intended for use in regulation of water and sediment quality, knowledge of the fraction of fish consumption that comes from harvesting is important. Some of the surveys covered in this report do have that kind of information. However, for the US general population and for the Washington State population there is not data available on the fraction of fish consumption that comes from harvesting.

Two Kinds Of Population Surveys

The two types of surveys that we have used as a basis for fish consumption rates in this report are food frequency questionnaires (Tulalip Tribes, Squaxin Island Tribe, Suquamish Tribe, Columbia River Tribes, Asian and Pacific Islanders) and dietary recall (NHANES survey). The NHANES survey did include a food frequency questionnaire, but not in a form that could be used, alone, to estimate fish consumption rates. It is useful, however in identifying fish non-consumers.

NHANES Survey

NHANES is an ongoing national sample survey of the United States population (NCHS, 2005) from which this report uses data collected during the years 2003 to 2006. This survey can be used to estimate fish consumption rates for the entire United States population.

The NHANES survey was conducted in clusters of counties (or single large counties or metropolitan areas), and part of the survey was administered by questionnaire and part of it through self-reporting. Specifically, for the two days' intake portion of the survey, the first day's data was collected by interviewers directly on site (within dwellings), while the intake for the second day was collected by telephone followup. [4]

In this report the analysis of rates based on the NHANES survey is limited to persons age 18 and over. This age cut is a common definition of “adult”, though it is not uniformly followed in other surveys.

EPA dietary analysis methods

[4] NHANES dietary documentation (2003): http://www.cdc.gov/nchs/nhanes/nhanes2003-2004/DR1IFF_C.htm

Our measurement of fish consumption from the NHANES survey is based on important and innovative work by the Office of Pesticide Programs at EPA. The EPA carried out an extensive exercise of converting named food items (such as pizza, Caesar dressing, etc.) into standardized recipes and the commodities that are components of those recipes. Thus, for each consumed food item named by survey respondents in the NHANES survey, the EPA provides a corresponding recipe with known ingredients, The EPA then grouped individual ingredients into several hundred 'commodity' groups, including six categories of fish or shellfish. Other examples from the EPA's long list of commodities include wheat flour, tomato puree and olive oil[5]. The EPA work enabled the survey respondents' list of food items eaten in each 24-hour recall period to be converted to quantities of fish and other food commodities.

The extensive EPA work to develop the conversion from conventionally named food items to commodities is thorough, capturing even small quantities of fish in a nominally non-fish dish. For example, the food "Dark-green leafy vegetable soup with meat, Oriental style", is itemized by the EPA for a 91 gram serving (a fifth of a pound) and includes 0.12 grams of fish, or 0.13% by weight. It seems likely that such low levels of fish consumption occur due to seasoning or other incidental (perhaps even unaware) usage of fish products by the consumer. It also seems that for most of these "sparse-fish" consumption days the source of these small quantities of fish would not be a local harvest of fish or shellfish. Rather, the fish ingredient might arise from a commercial product with a non-local source. One of the goals of this report is to estimate consumption of locally harvested fish or shellfish. The trace quantities of fish consumed on some of the days or as an average for two days in the NHANES survey probably originates from non-local sources. A listing of fish-containing food items which were consumed on days where the respondent consumed less than 1 g of fish (total) shows, predominantly, various types of cheese spread and, also, Caesar dressing. It seems unlikely that these items are created from locally harvested fish. These "sparse-fish" consumption items and days have been retained in the analysis, even though it is likely that they are not from local harvest. Only a small percentage of fish-consuming respondents had consumption days with less than 1g/day.

The fish consumption rates based on the NHANES data use the following six commodities[6]:

Fish-freshwater finfish;
fish-freshwater finfish, farm raised;
fish-saltwater finfish, other;
fish-saltwater finfish, tuna;
fish-shellfish, crustacean;

[5] The following link allows exploration of the commodities itemized for each recipe: http://fcid.foodrisk.org/recipes/
[6] Source for categories of fish commodities:
http://fcid.foodrisk.org/dbc/csv/ Download file: Commodity_Vocabulary.csv

fish-shellfish, mollusk

Survey estimates of fish consumption rates.
We have calculated USA adult fish consumption rates from the NHANES data using two methods. They first method, based on standard survey statistical methodology and a particular definition of "consumer", was used by the EPA in presenting NHANES fish consumption rates in the Exposure Factors Handbook (Chapter 10, 2011). Table 10-8, 10-10 and 10-12 of that report presents estimated rates, for fish consumers only, for the entire population of the USA and also broken down by various age, gender and ethnic groups. The definition of "consumer" used for calculation of rates presented in those tables is a person who consumed fish on at least one of the two days of the NHANES survey[7]. Using that definition we calculated the consumption rates for adult consumers only (age 18 and over) with two days reported on the 24-hour dietary recall[8].

NCI methodology for episodically consumed foods.

The NHANES survey includes data on what people ate on two selected days—chosen far enough apart to assure some level of independence of consumption on these days. While this method has the merit of capturing consumption before it fades from memory, it does not accurately portray consumption of foods that are consumed episodically, such as fish. This accuracy problem can be seen from Table 2 which compares the response to a) direct questions on the frequency during the past 12 months of eating certain food items that contain fish to b) the recall of consumption on two specified days.

Table 2. Fish consumption as reported for two observation days vs. fish consumption reported on the food frequency questionnaire (FFQ). FFQ responses collapsed to "ever" vs. "never".

Frequency of fish consumption on the FFQ	N adults	2-day recall: zero consumed on both days (%)	2-day recall: fish consumed on at least one day (%)	Total (%)
Never	680	88%	12%	100%
Ever	6,465	66%	34%	100%
All adults	7,145	68%	32%	100%

Notes: 1) Percentages are based on counts of adult respondents. 3) Adults, age 18 and over, NHANES survey, 2003-2006. Limited to adults who responded to both the food frequency questionnaire (FFQ) and the two 24-hour recall questionnaires.
3) The five relevant fish consumption questions are numbered FFQ0091-FFQ0095. Download questionnaire from: riskfactor.cancer.gov/diet/FFQ.English.June0304.pdf

[7] Personal communication: teleconference with staff of Office of Pesticide Programs, EPA, May 1, 2012
[8] Prior to carrying out these calculations, we verified that we had the correct data from NHANES and the correct computational method by calculating, comparing and reproducing exactly the fish consumption rates in the first numeric row of results in Table 10-12 of Chapter 12 of the Exposure Factors Handbook. (EPA, 2011.)

The table shows that a very large proportion (about two-thirds) of those who did report ever eating fish on the FFQ did not report fish consumption on either of the sampled recall days.

Thus, it is clear that there must be many true fish consumers included among those with no consumption reported on either of the two 24-hour recall days. Using the observed 2-day reporting to identify fish consumers and their consumption rates is going to have a lot of false negatives—true consumers who did not happen to report eating fish on either of the recall days. Of interest, as well, is the 12% of adults who reported never eating fish on the food frequency questionnaire but who did report some fish consumption on at least one of the two recall days[9]. While it appears that there is misclassification in both directions when the FFQ and the 24-hour recall days are compared. It appears safe to exclude from our further analysis of fish consumption rates from NHANES data those adults who reported "never" in response to the five fish consumption questions on the FFQ. These five questions collectively include any possible form of fish or shellfish consumption. Exclusion of these survey participant will remove a relatively small number of true fish "consumers" from our analysis dataset, but it is also very likely to remove a much larger number of true non-consumers. The exclusion is very likely to have a net effect of improving accuracy of our estimated fish consumption rates.

A second issue that it is important to understand when using the NHANES data is that the observed fish consumption on two recall days is not an accurate indication of usual intake. Consumers of fish do not eat the same quantities of fish every day. The large number of fish consumers (identified by the FFQ) who consumed fish on only one of the two days is an indication of this variation over time. And, even among those who did eat fish on two days, the amount eaten varies greatly between the days. Figure 1 shows a comparison of amount of fish eaten on the two days of recall for those adults who consumed fish on both days. Each point represents one survey adult.

[9] This small "inconsistent" group (82 adults) had average consumption rates similar to the "consistent" group (those who reported eating fish both on the food frequency questionnaire and on the 24-hour recall days.) The mean two-day fish consumption rates for the inconsistent and consistent fish consumers were 46.7 g/day and 54.1 g/day, respectively, with medians of 34.3 g/day and 37.6 g/day, respectively. These averages are based on adults with two days available for the 24-hour dietary recall and a non-missing response on the food frequency questionnaire.

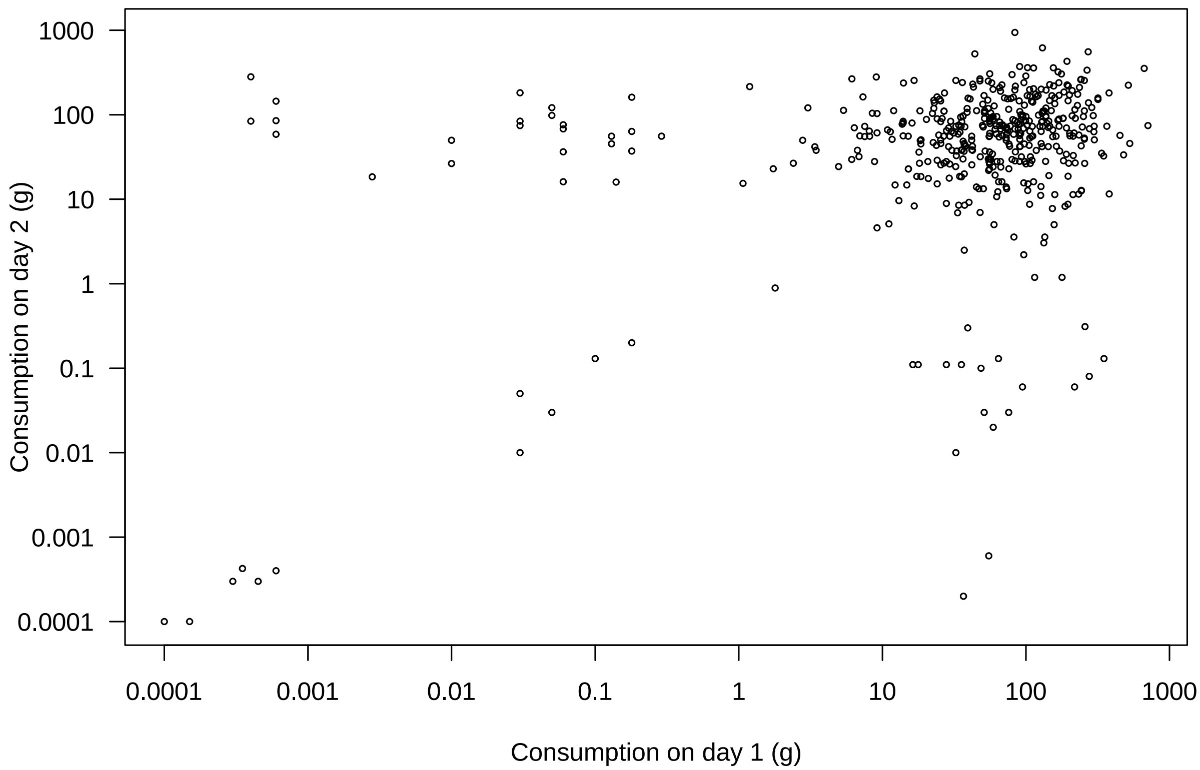

Figure 1. Scatterplot of day 1 vs. day 2 fish consumption amounts (grams) from 24-hour dietary recall.

Notes: NHANES 2003-2006. Includes N = 466 adult respondents with non-zero fish consumption on both recall days and a non-missing response to the five relevant fish consumption questions on the food frequency questionnaire.

The figure shows that it would not be uncommon to have a 10-fold change in fish consumption between two observed days. For example, the plot shows a number of points that represent people who consumed 10 grams on one day and 100 grams on another day. (See points in the figure located above 10 grams on the day 1 horizontal axis and across from 100 grams on the day 2 vertical axis.)

<u>Trace quantities of fish.</u> Figure 1 also shows that there are some adults who consumed minuscule quantities of fish on some days. Note the scattering of points that are below 1 gram on either or both days. These points may represent people who consumed fish which was present in small quantities in a nominally “non-fish” food item, such as Caesar salad dressing or cheese spread. An example is a respondent whose sole

consumption of fish on one of the consumption days was 0.03 grams from Caesar salad dressing[10].

Professor Janet Tooze and others have developed a methodology to estimate the usual intake of episodically consumed foods, such as fish (Tooze et. al., 2006; Kipnis et. al., 2009; Keogh, 2011). This methodology addresses the day-to-day variation in reported consumption and also addresses the occurrence of non-consumption days for those who are true consumers. The "NCI method", based on the work of Tooze et al, has been used to estimate consumption of a wide variety of dietary components. The National Cancer Institute web site shows consumption rates for 39 food groups based on the NCI method applied to data from the NHANES survey, 2001-2004[11].

In brief the NCI method fits a model for usual intake (grams/day) of a commodity, such as fish, based on data from a survey with reported consumption on two or more days[12]. The mean and percentiles of consumption are estimated from the distribution of usual intake, which is part of the fitted model. The model assumes:

1) There is an underlying distribution of true usual intake for the population being studied. The true intake for a given person might be thought of as their average daily intake—averaged over the course of a year, often reported as grams per day. The usual intake for a person does not have the ups and downs that occur with intake for any given day; the usual intake is a single number for each person. This usual, average or "true" intake would typically vary from person to person in the population. The set of values of usual intake would typically have relatively few people at very low or very high values of intake and relatively more people in between.

The set of usual intake values for a population do not have to be a "bell-shaped curve", but the true distribution, it is assumed in the NCI methodology, can be transformed to the normal (bell curve) distribution in a fairly flexible manner, specified by the methodology. (We note that fish consumption distributions tend to be skewed toward large consumption values and can often be approximated by the lognormal distribution; this phenomenon is consistent with the "transformation-to-the-bell-shape" assumption here.)

2) There is day to day variation in how much a person consumes of a commodity—on days when they do consume. The daily consumption varies around their usual intake.

3) There is a certain probability that a person will consume on any given day, and this probability can vary from person to person. E.g., there can be frequent and infrequent consumers of fish.

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[10] The respondent with sequence i.d. number 24231 consumed 0.03 grams of fish on day 2 from Caesar dressing.

[11] The consumption rates for various food groups is tabled at: http://riskfactor.cancer.gov/diet/usualintakes/pop/ The tables do include fish consumption, but not in the form needed for this project.

[12] The model requires data with two or more independent periods of observation, but the periods can be single days or any other unit of time, such as, for example, two 3-day periods.

4) There may be a correlation between consumption rate and the frequency of consumption. For many foods, those people who consume the food more frequently also consume more of it on the actual consumption days (Tooze et. al. 2006). That appears to be true for fish consumption among the USA adult population, as reflected in the NHANES 2003-2006 survey. Those individuals who consumed fish on both dietary recall days had a mean of 98 g fish consumption per day. Individuals who consumed on only one day had a mean of 86g consumption on the consumption day—12 g (13%) less than the more frequent fish consumers[13].

5) All survey respondents who are included in the analysis are assumed to be fish consumers. This includes the possibility that the consumption rate of some consumers may be very low—e.g., those who consumer fish only as it might appear in a condiment such as Caesar salad dressing. In using the NCI method in this report, survey respondents were excluded only if they reported on the food frequency questionnaire that they never consumed fish.

Additional notes on the NCI methodology are available in Tooze, 2006. An instructive webinar series featuring Dr. Tooze and others is available on the web[14].

Fish consumption rates: Tribal and Asian and Pacific islander surveys.

We used varying methodology—depending on information and data available—for estimation of fish consumption rates for the Native American Tribes in Washington and for the Asian and Pacific Islander Population in King County. We describe the methodology specific to each population in the appendices. All rates apply to consumers only.

Surveys of Recreational fishing and Creel surveys.

Fish consumption rates can also be derived from surveys of recreational fishers and from creel surveys. These surveys do not apply to a specific geographic population and are not included in this report. WDOE's technical support document includes a substantial section (with references to the literature) on creel and recreational surveys (WDOE, 2011.)

[13] Calculations are survey-based estimates. Only individuals with two dietary recall days are included in the calculations. There were 619 two-day consumers (median, 79 g/day) and 3,587 single-day consumers (median, 57g)..

[14] An excellent series of webinars, including a talk and materials by Dr. Tooze on the NCI method, are available at http://riskfactor.cancer.gov/measurementerror/ .

RESULTS

Fish consumption rates from the NHANES 2003-2006 study.

This report presents fish consumption rates derived from the NHANES survey using two methodologies. First, we present consumption rates using only the observed data (without any modeling) and standard survey estimation procedures based on the survey design. The method takes account of sampling weights, stratification and clustering. Second, we present estimates using the NCI method for handling episodically consumed foods. The method involves fitting a model to the data and obtaining estimates from the model; the method also takes account of survey design.

Fish consumption rates, NHANES, 2003-2006, consumer defined by *observed* consumption on two days.

In this approach to estimating fish consumption, the rates very literally reflect the observed consumption on two specific days in the life of each respondent. As noted earlier, the NHANES survey has recorded consumption of fish-containing items and other foods during two days of observation for each survey respondent. The definition of consumer used in the EPA's Exposure Factors Handbook (EPA, 2011) is a person who consumed fish on either or both of the two days. The rates in Table 3 are based on that definition but they are calculated from survey respondents age 18 and over. Appendix 2 includes an analysis that is helpful in understanding the impact of that definition on estimated rates.

Table 3. Fish consumption rates (g/day) for adult consumers only, USA population, based on NHANES 2003-2006. Consumers defined based on two days of consumption.

Species	N	Mean	Min	1%	5%	10%	25%	50%	75%	90%	95%	99%	Max
all	2,853	56.0	<0.1	<0.1	0.1	3.7	17.5	37.9	78.8	127.9	168.3	255.7	512.5
finfish	2,200	49.9	<0.1	<0.1	<0.1	0.1	14.6	34.6	68.9	115.3	149.8	217.0	512.5
shellfish	1,113	43.0	<0.1	<0.1	0.4	2.9	11.0	25.7	54.4	100.5	146.6	249.6	384.0

Notes: 1) "Consumers" are defined as those who consumed fish on at least one of the two dietary recall days. 2) Limited to those with data for two dietary recall days. 3) The minimum and maximum rates are as observed in the individual level data and are not products of the survey estimation procedure. 4) As input to the survey estimation procedure the fish consumption rate for an individual respondent is the mean consumption for the two observed days[15].

Fish consumption rates based on the NCI method, NHANES, 2003-2006.

[15] E.g., if the two days of consumption yielded zero grams and 50 grams, respectively, the mean would be 25 grams/day. Similarly, a consumption pattern of (10 grams, 90 grams) for the two days would yield a mean of 50 grams/day.

The rates in Table 4 are based on application of the NCI method to data collected by dietary recall from two specified days in the NHANES 2003-2006 surveys.
As noted in the methodology section, above, this report does not include fish consumption rates based on the NHANES survey for consumption of locally harvested fish. The NHANES survey did not include questions whose responses would provide a basis for estimating the “local catch” proportion of consumed fish or, more directly, the consumption in grams per day of fish obtained from local habitats,

While this report does not provide an estimate of the consumption rate of locally harvested fish for the general adult population of Washington, a simple calculation related to fishing licenses may be of interest. The percentage of the adult population with fishing licenses might be considered informally in the discussion of consumption rates.

Using data supplied by the licensing division of the Washington Department of Fish and Wildlife (WDFW), population estimates from Washington’s Office of Financial management, and (from NHANES data) the estimated fraction of the US population who are fish consumers, the rate of licensing in Washington 2008 would have been an estimated 24 licenses (of persons age 15 or over) per 100 fish-consuming persons age 18 and over. If every person with a license has only one license, then this would be approximately the percentage of adults with fishing licenses. This is <u>not</u> an estimate of the percentage of consumed fish that are locally harvested,

Table 4. Fish consumption (g/day) estimated from NHANES 2003-2006 by the NCI method. Consumers only. Adults (age 18+).

				Percentile									
	N	**Mean**	**Min**	**1st**	**5th**	**10th**	**25th**	**50th**	**75th**	**90th**	**95th**	**99th**	**Max**
All fish	6,465	18.8	0.0	0.9	2.0	3.0	6.2	12.7	24.8	42.5	56.6	90.8	941.2
finfish	6,465	14.0	0.0	0.6	1.4	2.1	4.3	9.0	18.1	31.8	43.3	72.7	941.2
shellfish	6,465	5.4	0.0	0.1	0.2	0.4	0.9	2.4	6.0	13.2	20.5	43.8	704.9

Notes: 1) Minimum and maximum values are from observed survey data and are not estimated by the NCI method. 2) NHANES 2003-2006 data were restricted to those survey respondents with a) two days of data from the 24-hour dietary recall, b) non-missing data on the food frequency questionnaire, and c) some fish consumption reported on the food frequency questionnaire (i.e., at least one of the five fish consumption questions on the FFQ was ***not*** *answered "never" for frequency of consumption.)*

Native American Tribes

Tulalip Tribes

Individual-level data were available by permission of the Tulalip Tribes. All reported consumption rates were derived directly from the individual level data.

Table 5. Consumption of various species groups of fish by the Tulalip Tribes, consumers only, g/day, by source of fish consumed: all sources or harvested from Puget Sound.

Species	Source of fish	N	Mean	50%	75%	80%	85%	90%	95%	Max
All	all	73	82.2	44.5	94.2	119.6	141.5	193.4	267.6	710
Finfish	all	72	44.1	22.3	49.1	59.1	65.1	109.6	203.9	278.3
Shellfish	all	61	42.6	15.4	40.1	59.1	82.7	112.9	140.8	461.4
Non-anadromous	all	71	45.9	20.1	52.4	65.6	80.2	118.4	150.6	469.8
Anadromous	all	72	38.1	16.8	43.3	46.4	57.3	92.1	191.1	265.3
All	Puget Sound	71	59.5	29.9	75	79.4	122.6	138.5	237.4	450
Finfish	Puget Sound	71	31.9	13	33.1	42.4	55.4	78.4	145.8	236.7
Shellfish	Puget Sound	53	36.9	14.2	40.1	52.7	85.8	111.4	148.3	230.7
Non-anadromous	Puget Sound	59	35.5	14.8	38.8	48.7	67.6	109.2	145	233.8
Anadromous	Puget Sound	70	30.4	11.8	32.4	39.3	55.1	66	148.2	236.7

Squaxin Island Tribe

We used published results—not individual level data—to estimate the consumption rates for the Squaxin Island Tribe in Table 6. The calculations are described in Appendix 3. Appendix 4 includes an evaluation of the use of published fish consumption rates (as a starting point for calculations) vs. use of individual level (“raw”) data.

Table 6. Consumption in g/day, Squaxin Island Tribe, consumers only, mean and percentiles, by species group and source.

Species	Source	N	Mean	50%	75%	90%	95%
Anadromous	All	117	55	25.2	65.6	127.9	170.6
Shellfish	All	86	23.1	10.3	23.8	53.9	83.4
Finfish	All	117	65.4	31.3	82.1	149.4	207.5
All fish	All	117	83.5	44.4	94.2	205.3	279.5
Non-anadromous	All	NA	28.5	15.2	32.2	70.2	95.5
Anadromous	Puget Sound	117	44	20.2	52.5	102.3	136.5
Shellfish	Puget Sound	86	14.3	6.4	14.8	33.4	51.7

Species	Source	N	Mean	50%	75%	90%	95%
Finfish	Puget Sound	117	43.3	20.8	54.4	99	137.5
All fish	Puget Sound	117	52.4	27.8	59	128.7	175.2
Non-anadromous	Puget Sound	NA	8.4	4.5	9.5	20.6	28.1

Columbia River Tribes

The 1994 report of a survey of Columbia River Tribes reports the mean and various consumption rates for all adult fish consumers (CRITFC, 1994, Table 10, pages 85-86.) The percentages presented in CRITFC Table 10 were derived from data that were statistically weighted to account for the relative sizes of the tribes. Our estimated consumption rates for the Columbia River tribes in Table 7, below, are derived from the results in CRITFC Table 10 and from other results in the report.

The CRITFC report gives percentages of consumers corresponding to each observed value of consumption (g/day.) For example, 6.5% (weighted percentage) of consumers were reported to consume 97.2 g/day. We used the specific individual consumption rates and their weighted percentages in CRITFC Table 10 to derive mean and percentiles of consumption using standard procedures for estimating the mean and percentiles from survey (weighted) data (Binder, 1991.) Other data in the CRITFC report were used to derive proportions of fish harvested from the Columbia River and other statistics needed to produce our various categories of fish consumption in Table 7 here. Details are in Appendix 3.

Table 7. Mean and percentiles of consumption rates by species group and source, Columbia River Tribes, adult consumers only.

Species	Source	N	Mean	50%	75%	90%	95%	99%	Max
All	all	464	63.2	40.5	64.8	130.0	194.0	486.0	972
non-anadromous	all	464	32.6	20.9	33.4	67.0	99.9	250.3	500.7
anadromous	all	464	30.6	19.6	31.4	63.1	94.1	235.7	471.3
All	Col. River	464	55.6	35.6	57.0	114.4	170.7	427.7	855.4
non-anadromous	Col. River	464	28.6	18.4	29.4	58.9	87.9	220.3	440.6
anadromous	Col. River	464	27	17.3	27.7	55.5	82.8	207.4	414.8

Suquamish Tribe

Estimates for consumption of Puget Sound-harvested seafood by fish consumers in the Suquamish Tribe in g/day are available for all fish (combined) and for all except anadromous fish in the following document: "Selected Suquamish Tribe Seafood Ingestion Rates, Consumers Only" (Polissar, 2007.) The document includes the methodology used to derive rates. Fish consumption rates in that document were calculated from data available at the individual level. Selected rates presented in that

document are shown in the rows in Table 8 corresponding to 1) all species, Puget Sound source and 2) all species except anadromous, Puget sound source.
All other rates in the table, aside from those in the two designated rows, were calculated in a different way, using methods described in Appendix 3.

Table 8: . Mean and percentiles of consumption rates by species group and source, Suquamish Tribe, adult consumers only.

Species	Source	N	mean	50%	75%	80%	85%	90%	95%	Max
All	All Sources	92	NA	128.5	284.2	320.6	390.4	489.0	796.9	NA
Non-anadromous*	All Sources	92	NA	70.8	170.2	218.8	267.5	387.8	624.5	NA
Shellfish	All Sources	91	NA	64.7	145.1	182.1	230.8	363.4	615.4	NA
All	Puget Sound	91	165.1	57.5	220.7	250.4	300.9	396.7	766.7	1248.2
Non-anadromous*	Puget Sound	89	125.6	49.1	116.2	177.4	211.1	379.8	674.1	1095.5
Shellfish	Puget Sound	NA	NA	59.1	121.9	153.0	193.8	305.3	516.9	NA

*Includes the following species groups: pelagic, bottom-feeding, and shellfish. The rates do not include species in Group F (other finfish) and Group G (other shellfish) defined in Table T-4 of Suquamish, 2000.
NA: not available or data needed for computation were not available.

Asian and Pacific Islander

Seafood consumption rates for the Asian and Pacific Islander (API) community were estimated in the Sechena, 1999 Appendix M3 of the report provides mean and 50th, 75th and 90th percentiles of consumption in g/kg-day of a variety of species groups. A 2005 EPA report (Kissinger, 2005) presented a re-analysis for consumers only which took account of harvesting. That report covers the methodology underlying the rates. Excerpts from Table 5 of that report are offered in Table 9 of this report. Whereas for most species the uncooked weight of fish consumed was calculated, for some species the survey calculated cooked weights, since cooking was needed to provide better access to the edible portion of the organism[16]. The rates reported here include no adjustment for cooking effect and they may be slightly biased downward. See Kissinger, 2005, for rates adjusted to remove the cooking effect.

Table 9. Fish consumption rates (g/day), adult Asian and Pacific Islanders resident in King County, selected percentiles by species group and source.

[16] Kissinger, 2005 notes: "However consumption of the following shellfish species was recorded in terms of cooked weight: butter clams, cockles, crab, geoducks, horse clams, macoma, manila/little neck, moon snail, mussels, oysters, razor clams, and scallops. These organisms were steamed or boiled in order to facilitate removal of edible tissue from the shell."

Species group	Source	No. consumers	50%	90%	90%
All	harvested	125	6.5	25.9	58.8
Non-anadromous	harvested	112	6.2	37.9	54.1
All	all	202	74.0	226.9	286.1

Adapted from Table 5 of Kissinger, 2005.

Discussion

We have presented a number of fish consumption rates that may be relevant to the process of water and sediment quality regulation. The rates span a wide range, and it will be important to users of these rates to attempt to match the particular rate regimen to the population whose water and sediment quality is to be regulated.

The rates are of varying quality and depend on assumptions to a varying extent. All of the rate regimens depend on the assumption that people can remember what they have eaten—either in the last 24 hours or on the general frequency of consumption of specified kinds of fish or shellfish over an extend period. Taking the rates at face value also means that we regard memory as correctly representing the actual quantity of fish eaten.

While the rates are not perfect, they are meaningful. We have not supplied standard errors or confidence intervals ("margins of error") for the rates, but the sample sizes involved in the various studies provide some guidance as to which are more or less prone to random error.

One pitfall to avoid in using these rates is to assume that the 95th percentile of consumption—a percentile that is likely to play a prominent role in discussions—is determined only by the few highest observed consumption values. For example, the Tulalip Tribes survey had 73 participant, and the 95th percentile of consumption would fall between the third and fourth largest observed consumption rates. We sometimes hear the fallacy that in a case like this the 95th percentile of consumption <u>only</u> depends on four observations. Not true. Aside from the top four observations in the Tulalip Tribes' data, there are the other 69 observations pushing the top four up to the top. Dropping any of the lower observations would change the 95th percentile, as would dropping any of the top four observations. All of the observations have weighed in on determining the 95th percentile, or any percentile, or the mean. Nevertheless, it is certainly true that the 95th percentile is not as well determined as a more central percentile, such as the median.

The following issues influence fish consumption rates or are considerations in their use.

<u>Survey and analysis methodologies.</u> The surveys and analysts of those surveys differ in their definition of a fish consumer, and the definition has a very substantial impact on the calculated consumption rates. The most inclusive definition is used in the NCI method (applied here to the USA survey data form NHANES). In the NCI methodology (Tooze, 2006) all respondents entered into the analysis of rates are considered consumers, though the amount consumed may be from very little on up. In our report those NHANES national survey respondents who indicated that they never consume fish were excluded from the analysis, so the balance of respondents are very likely to be true fish consumers. The definition of consumer used in the Exposure Factors Handbook (EPA, 2011, Chapter 10)—with fish consumption rates based on the NHANES data—is a person who consumed fish on either of the two dietary recall days. This definition stays very close to the observed data but is perhaps too literal. We have shown in Appendix 2 that using one day vs. two days of observation to define a consumer has a drastic influence on the calculated consumption rates. Consumption rates will decline as more days are surveyed, are used to define a consumer and are averaged to estimate a consumption rate for the consumers so defined. Thus, the "consumer" considered for analysis—in this observation-based definition of a consumer—depends on what information the survey captures. The true consumption of each survey respondent is, however, obviously independent of what the survey discovery mechanism is. Nevertheless, it will be valuable if results from the observation-based definition of a consumer, as used in the Exposure Factors Handbook, continue to be presented, since there will always be some demand for rates that are not based on modeling, no matter how realistic the modeling is.

The NCI method uses a model to estimate the distribution of fish consumption rates, and the percentiles of rates are likely to be closer to the truth than with the strict, observation-based definition of a consumer. The model assumptions, described earlier in this document, are realistic, including the variation in people's daily decisions about consuming vs., not consuming fish and also including variations in the amount of fish consumed on a "fish day," and other features. The figure below shows the results of a simulation study of the NCI method vs. the observation-based method of defining consumption[17]. A hypothetical "survey" with two observation days (as in NHANES) was simulated and the distribution of consumption rates was compared between a) the true distribution of usual consumption, b) a 2-day mean of observed consumption per respondent (all respondents—observed consumers and observed non-consumers), and c) the NCI method. Selection (b) is not the approach in the Exposure Factors Handbook, but the simulation is, nevertheless, useful as a comparison of two methods to "the truth." Note that the NCI method well approximates the truth and the distribution of the 2-day method is quite different from the truth; in particular, the two-day method has an excess of zero or very low consumption rates.

[17] The figure is a slide from Dr. Janet Tooze's webinar 3 at the following link: http://riskfactor.cancer.gov/measurementerror/

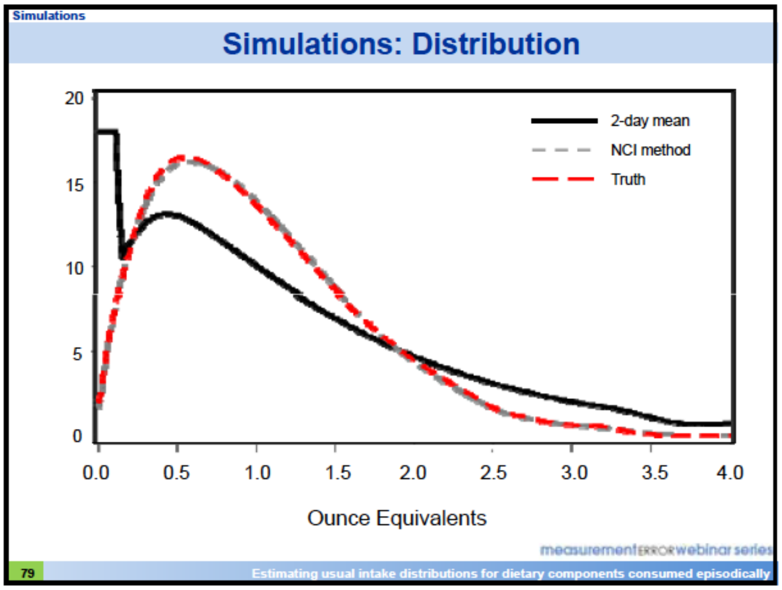

Figure 2. A simulation example of the NCI method at work. See text.

This report puts proposes the USA consumption rates derived from the NCI method (Table 4) as the appropriate rates to represent fish consumption of the general population of the United States.

Outliers. This report is true to the survey data, as obtained. No observed values have been changed or deleted. While some of the consumption rates for individuals are large, none appear to be impossible. They may excite suspicion or even wonder, but they are still within the realm of possibility. There is not an accepted definition of outlier that should be mechanically applied here.

We have encountered observations in other settings that appear to have arisen from a population that differs from that under study. It might be a key entry error, recording error or a contamination of the study by a truly aberrant person or entity. The usual procedure is to work back upstream in the data collection process and see what happened. That is not possible here, but, again, though there may have been "outliers" by formal testing rules, none of the observations that we have come across appear to be impossible. In the 2003-2006 NHANES survey described earlier, the highest adult consumption rate encountered in our data analysis of over 6,400 respondents was 941 g/day, based on two days of observation. Only two days of observation among such a large group of people might, indeed, turn up some unusually large values that are higher than the person's usual (average) intake. Nevertheless, this daily intake (a little over two pound per day, uncooked weight) seems possible among this large group of people.

An additional fact is that an outlier search tends to be one-sided. A large observation draws attention, but perhaps some of the very small observations should be examined, too, if the spirit of examination is to be unbiased. For example, a very small salmon consumption rate might appear anomalous for an individual in a Native American Tribe that values salmon culturally, socially and as a favorite food.

Thus statistically, we have allowed the data to stand, finding no individual consumption rates so egregious as to require ejection.

Suppression. Some authors have suggested that current fish consumption rates of the Native American Tribes are suppressed compared to historical consumption rates and that this suppression affects the health of members of the Tribe. (See, for example, Donatuto & Harper, 2008.) Hopefully, studies underway will provide some insight into the historical consumption rates. This report offers no opinion or finding on the suppression issue. However, since health outcomes are a factor in setting regulations, and given the appearance of “suppression” as a potential health risk factor in the peer-reviewed literature, our statistician’s laundry list of factors to be discussed in choosing fish consumption rates would include consideration of suppression as a potential health risk factor.

Does national data represent Washington State? We do not know of a representative survey that covers fish consumption among the general adult population in Washington State. We have developed consumption rates from the NHANES study data for the USA as a whole, but we do not know how similar fish consumption rates are between the USA and Washington State.

It may be possible to obtain a subset of NHANES data that covers the coastal states of the USA (vs. interior states), where fish consumption rates may be more similar to those in Washington. However, the geographic identifiers in NHANES are masked and a lengthy application and approval process is needed to obtain geographic data. Washington has about 2% of the USA population, so the NHANES sample size for the State is likely to be too small. The collection of coastal states would be more likely to have a sufficient sample size. There would be statistical issues to address in using a subset of the NHANES geographic coverage, when the survey was designed to represent the USA and not designed to represent individual states.

Farmed and purchased fish. We have tried to estimate the portion of fish consumption that comes from harvest of fish by individuals. However, even purchased fish may included some product that was farmed from local waters or was harvested locally and ended up in locally sold commercial products. Similar to the suppression issue noted above, this is a topic for which we have obtained no data and, thus, have no comment on it. We do not know if the magnitude of this source of fish is large enough to warrant discussion or further investigation.

About the authors.

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Aleksandr Y. Aravkin received a PhD in mathematics (optimization) and an MS in statistics from the University of Washington in 2010. Dr. Aravkin has been collaborating with The Mountain-Whisper-Light since 2007 and is currently a postdoctoral fellow at the University of British Columbia. His contributions for this project include literature review of underlying survey materials, methodology and review.

Patrick Danaher has a Master's degree in biostatistics from the University of Washington and is a PhD candidate in the same program. His involvement in the study includes methodology, calculation of fish consumption rates for the Native American and Asian and Pacific islander surveys, review of creel/recreational fishermen surveys, writing and review.

John Kalat is a project employee of The Mountain-Whisper-Light Statistics. He worked for the SHARP Program at the State of Washington Department of Labor and Industries for 13 years, managing very large data projects, data reduction for use by researchers and methods of improving the efficiency and effectiveness of data projects. His involvement in this project includes locating and accessing appropriate data, data management of large files and review of the report.

Glossary

CRITFC: Columbia River Inter-Tribal Fish Commission
EFH: Exposure Factors Handbook
EPA: U.S. Environmental Protection Agency
FCR: fish consumption rate
FFQ: food frequency questionnaire

NHANES: National Health and Nutrition Examination Survey
NCI: National Cancer Institute
SHARP: Safety & Health Assessment & Research for Prevention, State of Washington Department of Labor and Industries
TSD: Technical support document.
WDFW: Washington Department of Fish and Wildlife
WDOE: Washington Department of Ecology

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Appendices

Appendix 1. Summary table of consumption rates.

Table A-1 presents a summary of mean, median and 95th percentile rates from earlier tables. For the USA population, only the rates calculated by the NCI method are presented.

Table A-1. Fish consumption rates (g/day) by population, species group and source of fish consumed: USA population

Population	Species	Source	N	Mean	Median	95%tile
USA*	All	All	6,465	18.8	12.7	56.6
USA*	Finfish	All	6,465	14.0	9.0	43.3
USA*	Shellfish	All	6,465	5.4	2.4	20.5
USA*	All	Harvested	NA	NA	NA	NA
Tulalip	All	All	73	82.2	44.5	267.6
Tulalip	Finfish	All	72	44.1	22.3	203.9
Tulalip	Shellfish	All	61	42.6	15.4	140.8
Tulalip	Non-anadromous	All	71	45.9	20.1	150.6
Tulalip	Anadromous	All	72	38.1	16.8	191.1
Tulalip	All	Puget Sound	71	59.5	29.9	237.4
Tulalip	Finfish	Puget Sound	71	31.9	13	145.8
Tulalip	Shellfish	Puget Sound	53	36.9	14.2	148.3
Tulalip	Non-anadromous	Puget Sound	59	35.5	14.8	145
Tulalip	Anadromous	Puget Sound	70	30.4	11.8	148.2
Squaxin Island	Anadromous	All	117	55	25.2	170.6
Squaxin Island	Shellfish	All	86	23.1	10.3	83.4
Squaxin Island	Finfish	All	117	65.4	31.3	207.5
Squaxin Island	All	All	117	83.5	44.4	279.5
Squaxin Island	All except anadromous	All	NA	28.5	15.2	95.5
Squaxin Island	Anadromous	Puget Sound	117	44	20.2	136.5
Squaxin Island	Shellfish	Puget Sound	86	14.3	6.4	51.7

Population	Species	Source	N	Mean	Median	95%tile
Squaxin Island	Finfish	Puget Sound	117	43.3	20.8	137.5
Squaxin Island	All	Puget Sound	117	52.4	27.8	175.2
Squaxin Island	All except anadromous	Puget Sound	NA	8.4	4.5	28.1
Col. River	All	All	464	63.2	40.5	194.0
Col. River	Non-anadromous	All	464	32.6	20.9	99.9
Col. River	Anadromous	All	464	30.6	19.6	94.1
Col. River	All	Col. River	464	55.6	35.6	170.7
Col. River	Non-anadromous	Col. River	464	28.6	18.4	87.9
Col. River	Anadromous	Col. River	464	27	17.3	82.8
Suquamish	All	All	92	NA	128.5	796.9
Suquamish	All excluding anadromous	All	92	NA	70.8	624.5
Suquamish	Shellfish	All	91	NA	64.7	615.4
Suquamish	All	Puget Sound	91	165.1	57.5	766.7
Suquamish	All excluding anadromous	Puget Sound	89	125.6	49.1	674.1
Suquamish	Shellfish	Puget Sound	NA	NA	59.1	516.9
A & PI	All	Harvested	125	NA	6.5	58.8
A & PI	Non-anadromous species	Harvested	112	NA	6.2	54.1
A & PI	All	All	202	NA	74.0	286.1

*Based on the NCI method.

Appendix 2. Notes on the NCI method and on NHANES data.

Use of the NHANES FFQ to define never-consumers of fish.

The NHANES food frequency questions used to screen for never-consumers of fish are shown below (downloaded from *: riskfactor.cancer.gov/diet/FFQ.English.June0304.pdf*.) In order to be considered as a never-consumer, we required a "never" answer to questions #91, #93-95, **and**, also, either (a) or (b) to be true: [(a) a "never" answer to #92 and no answer—blank—to #92a]; [(b) an "almost never or never" answer to #92a].

91. How often did you eat **smoked fish** or **seafood** (such as smoked salmon, lox, or others)?

◯ NEVER

◯ 1–6 times per year	◯ 2 times per week
◯ 7–11 times per year	◯ 3–4 times per week
◯ 1 time per month	◯ 5–6 times per week
◯ 2–3 times per month	◯ 1 time per day
◯ 1 time per week	◯ 2 or more times per day

92. How often did you eat **sushi**?

◯ NEVER **(GO TO QUESTION 93)**

◯ 1–6 times per year	◯ 2 times per week
◯ 7–11 times per year	◯ 3–4 times per week
◯ 1 time per month	◯ 5–6 times per week
◯ 2–3 times per month	◯ 1 time per day
◯ 1 time per week	◯ 2 or more times per day

Question 93 appears on the next page.

Over the past 12 months...

92a. How often did the **sushi** you ate contain **raw fish** or **seafood** (including shellfish)?

◯ Almost never or never
◯ About 1/4 of the time
◯ About 1/2 of the time
◯ About 3/4 of the time
◯ Almost always or always

93. How often did you eat **raw oysters, raw clams,** or **other raw fish** (not including raw fish in sushi)?

◯ NEVER

◯ 1–6 times per year	◯ 2 times per week
◯ 7–11 times per year	◯ 3–4 times per week
◯ 1 time per month	◯ 5–6 times per week
◯ 2–3 times per month	◯ 1 time per day
◯ 1 time per week	◯ 2 or more times per day

94. How often did you eat **fish sticks** or **fried fish** (including fried seafood or shellfish)?

◯ NEVER

◯ 1–6 times per year	◯ 2 times per week
◯ 7–11 times per year	◯ 3–4 times per week
◯ 1 time per month	◯ 5–6 times per week
◯ 2–3 times per month	◯ 1 time per day
◯ 1 time per week	◯ 2 or more times per day

95. How often did you eat **all other fish** or **seafood** (including shellfish) that was **NOT FRIED, SMOKED,** or **RAW** ?

◯ NEVER

◯ 1–6 times per year	◯ 2 times per week
◯ 7–11 times per year	◯ 3–4 times per week
◯ 1 time per month	◯ 5–6 times per week
◯ 2–3 times per month	◯ 1 time per day
◯ 1 time per week	◯ 2 or more times per day

Comment on "consumer only" definition used with NHANES data.

Table A-2 shows consumption rates when a "consumer" is defined as a) one who consumes fish on **either** of the two dietary recall days of the NHANES survey and the consumption rate is the average of consumption on the two days (first numeric row of the table); b) one who consumes fish on day 1 of the 2 days of dietary recall; and, c) one who consumes fish on day 2 of the 2 days of dietary recall. The rates in the table are based on a standard survey estimation procedure using the statistical weights and the survey design. The first three numeric rows do not use the NCI method. The last numeric row—based on the NCI method—is included for comparison.

Note that the consumption rate rises considerably when consumers detected on only one day of consumption are included (second and third numeric rows) compared to the average for two days (first numeric row.) The observation-bound definition of consumer tends to underestimate the number of consumers and overestimate consumption rates for "consumers", a bias that decreases as the number of observation days increases and consumers are defined as those who consume fish on any of the observed days. The NCI method does draw on all of the observed data collected on the two dietary recall days, including the occurrence of zero consumption on either or both days.

Table A-2. Fish consumption rates (g/day) for adult consumers only, USA population, based on NHANES 2003-2006, all fish and shellfish species combined, using survey estimation.

Consumption on:	N	Mean	Min	1%	5%	10%	25%	50%	75%	90%	95%	99%	Max
Either day*	2,853	56.0	<0.1	<0.1	0.1	3.7	17.5	37.9	78.8	127.9	168.3	255.7	512.5
Day 1	1,685	93.9	<0.1	<0.1	0.1	5.4	28.9	63.6	128.4	212.7	266.2	477.4	957.2
Day 2	1,651	94.8	<0.1	<0.1	0.1	5.8	29.6	66.5	133.1	218.7	279.6	446.9	941.2
Comparison: NCI method**	6,465	18.8	0.0	0.9	2.0	3.0	6.2	12.7	24.8	42.5	56.6	90.8	941.2

Notes: 1) "Consumers" are defined as those who consumed fish on at least one of the two dietary recall days (first numeric row), on Day 1 (second numeric row) or Day 2 (third numeric row), respectively. 2) Limited to those with data for two dietary recall days. 3) The minimum and maximum rates are as observed in the individual level data and are not products of the survey estimation procedure.
*Fish consumption on either dietary recall day or both days. The rates for these "consumers" is the mean of fish consumption for the two survey days.
**Calculated using the NCI method. See Table 4 and accompanying description for methodology.

Appendix 3. Methodologic notes: Surveys of Native American Tribes and of Asian and Pacific islanders.

Tulalip Tribes.

All statistics of fish consumption rates were calculated from individual level data. We used two datasets: 1) "Tulalip-Part-Site.sav" (an SPSS file), which contained the data on the percent of each species group harvested from Puget Sound. 2) "adultoriginal.dta", which contained consumption rates in g/kg-day and weights in kg. The "outliers which were modified for analysis in the original publication (Toy, 1996) are unmodified here.

In order to calculate an individual's consumption of fish in a species group X (e.g., "all fish") in g/day, we performed the following procedure:

Define:

Rate_grpX: gkgday: An individual's consumption rate (g/kg-day) of fish in species group X.

BW: The individual's body weight in kg.

Percent_PS_grpX: The percent of the individual's consumption of species group X that was harvested in Puget Sound. The percent is used as a decimal proportion during calculations.

We then calculate consumption in g/day as:

Rate_grpX_gday = Rate_grpX_gkgday * BW

Finally, we calculate consumption of Puget Sound-harvested fish in g/day as:

Rate_grpX gday_PS = Rate_grpX_gkgday * BW * Percent_PS_grpX

In order to calculate an individual's Puget-sound-harvested consumption rate for aggregate species groups, such as finfish or all fish, we add together their Puget-sound-harvested consumption rates for the appropriate individual species groups. The percentiles of fish consumption rates for a species group or the aggregate of species groups are then calculated from the corresponding distribution of consumption rates for individual adult survey respondents.

Squaxin Island Tribe.

All statistics of fish consumption rates were calculated starting from published data. Percentiles and other statistics of consumption, for consumers only, have been published in g/kg-day (Polissar, 2006, Table A1.S.) To convert these results to g/day, we multiplied the reported statistics by the mean weight of the respondents, which we derived as the weighted mean of the male and female body weights presented in Table A1 of Toy et al (1996.) To estimate consumption rates of seafood harvested from Puget

Sound, we employed a similar approach. For a given group of species group, for example, “anadromous,” we multiplied the reported g/kg-day statistics by mean body weight and by the mean proportion of the species group that was harvested in Puget Sound. In formulaic format, the following were the calculations.

In order to convert a published statistic (“stat”) in g/kg-day to another format, define:

stat_in_g/kg-day:	the published statistic in g/kg-day
grp_mean_PS:	the mean proportion of the species group’s consumption harvested in Puget Sound
meanBW:	the mean body weight of the tribe

and compute:
Stat_in_g/day = stat_in_g/kg-day * meanBW
Stat_in_g/day, harvested in PS = stat_in_g/kg-day * meanBW * grp_mean_PS

For a group of species for which the percent harvested from Puget Sound was not tabulated in available publications (e.g., finfish as a combination of all finfish species groups) we estimated the average proportion of the species group that was harvested in Puget Sound as follows. We calculated the proportion harvested from Puget Sound for a combined set of species groups as a weighted mean of the individual species group's mean proportion harvested from Puget Sound (Toy, et al, 1996, Table 11.) The statistical weight per species group was the published mean consumption rate (g/kg-day) for that group.

Published results were not available for consumption of non-anadromous fish (as combined of multiple species groups). We used a simple proportionality method to estimate means and percentiles for this combination of species groups. We multiplied each statistic (mean or percentile of all-fish consumption rates) by the proportion of all fish consumption represented by non-anadromous fish. This proportion was, in turn, calculated as a) the sum of mean consumption rates for all non-anadromous fish species groups, divided by b) the mean consumption rate for all fish. Note: this procedure assumes that all consumers of fish consumed some non-anadromous fish and that the proportion of consumption due to non-anadromous fish is constant across all levels of fish consumption—a very strong assumption. We performed this proportionality adjustment to derive estimated rates for consumption of non-anadromous fish obtained from all sources and for non-anadromous fish harvested from Puget Sound.

In more formulaic notation:

For a set of species groups, for example “finfish” or “all fish”, to convert a published statistic summarizing consumption in g/kg-day to consumption in g/day harvested from the Puget Sound, take:

Take:

MeanGrpA:	The mean consumption of anadromous fish
MeanGrpB:	The mean consumption of pelagic fish
MeanGrpC:	The mean consumption of bottom-feeding fish
MeanGrpD:	The mean consumption of shellfish
MeanGrpO:	The mean consumption of other fish
GrpA_mean_PS:	The mean proportion of anadromous fish consumed that were harvested in the Puget Sound.
GrpB_mean_PS:	The mean proportion of pelagic fish consumed that were harvested in the Puget Sound.
GrpC_mean_PS:	The mean proportion of bottom-feeding fish consumed that were harvested in the Puget Sound.
GrpD_mean_PS:	The mean proportion of shellfish consumed that were harvested in the Puget Sound.
GrpO_mean_PS:	The mean proportion of other fish consumed that were harvested in the Puget Sound.

Then the mean proportion of finfish harvested in the Puget Sound is:

Finfish_mean_PS = (MeanGrpA * GrpA_mean_PS + MeanGrpB * GrpB_mean_PS + MeanGrpC * GrpC_mean_PS)/(MeanGrpA + MeanGrpB + MeanGrpC)

And the mean proportion of all fish harvested in the Puget Sound is:

Allfish_mean_PS = (MeanGrpA * GrpA_mean_PS + MeanGrpB * GrpB_mean_PS + MeanGrpC * GrpC_mean_PS + MeanGrpD * GrpD_mean_PS + MeanGrpO * GrpO_mean_PS)/(MeanGrpA + MeanGrpB + MeanGrpC + MeanGrpD + MeanGrpO)

Suquamish Tribe

In Table 8, the estimated consumption rates (consumers only) for all seafood harvested from Puget Sound and for all seafood harvested from the Puget Sound, <u>excluding</u> anadromous fish, were transcribed directly from an earlier report (Polissar, 2007.) The other estimated consumption rates in Table 8 for all categories of fish consumption obtained from all sources were converted to g/day starting from consumer-only rates (in g/kg-day) supplied to WDOE by the Suquamish Tribe and based on the work of one of the Suquamish survey statisticians (Liao, 2002.) We converted g/kg-day rates to g/day by multiplying each reported statistic in g/kg-day by the Suquamish survey participants' mean weight in kg—reported as 79 kg in Table T-2 of the original Suquamish report (Suquamish 2000.)

Specifically, we define:

Published_stat_in_gkgday: The published mean or percentile consumption rate in g/kg-day

Mean_BW: The mean body weight in kg of the respondents.

We then calculate:
Stat_in_g/day = Published_stat_in_gkgday * Mean_BW.

Finally, we derive the estimates for consumption of shellfish harvested in Puget Sound by multiplying the estimates for consumption of shellfish from all sources by 0.84, the average proportion of shellfish consumed that was harvested in Puget Sound.

Columbia River Tribes

From manual measurements on Figure 7 of the CRITFC report (CRITFC, 1994) the mean intake of anadromous fish among all consumers and non-consumers of anadromous fish is 28.5 g/day. We convert this quantity to mean intake amongst consumers of fish by dividing this number by 0.93, the estimated percent of tribe members that consume seafood. (See page 69 of the CRITFC report.) Table 10 of the same publication reports that the mean intake of all fish by consumers of fish is 63.2g/day. Thus, we can conclude that approximately 48.5% of all seafood consumed by the tribes surveyed is anadromous. We use this quantity to estimate mean and percentile consumption rates of anadromous or non-anadromous fish by multiplying the "all-fish" mean and percentiles of consumption by 0.485 and 0.515, respectively.

Finally, the CRITFC report (page 45) offers an estimate that 88% of fish consumed by the tribes surveyed is harvested from the Columbia River. To estimate mean and percentile intakes of fish harvested in the Columbia River, we multiply our results for fish from all sources by 0.88.

Asian and Pacific Islanders

Seafood consumption rates for the API community were estimated in the 1999 EPA report "Asian & Pacific Islander Seafood Consumption Study in King County, WA." Appendix M3 of the report provides mean and 50th, 75th and 90th percentiles of consumption in g/kg-day of a variety of species groups.

Additional analysis of the API consumption rates were carried by EPA and are reported in Kissinger, 2005, and the methodology is described in that report.

Appendix 4. Fish consumption rates calculated from a proportionality assumption vs. rates calculated from individual ("raw") data.

In various places in this report we have presented means and percentiles of consumption rates derived by using a simple proportionality assumption. In this appendix we carry out a brief assessment of the validity of that approach

For the Squaxin Island Tribe, mentioned as an example here, individual level data were not available for use in this report. Therefore we have taken consumer-only shellfish consumption rates (mean and percentiles from Polissar, 2006) and multiplied them by the Squaxin Island Tribe's mean body weight (from the survey) to yield the estimated percentiles and mean of shellfish consumption rates in g/day. We have then multiplied these percentiles and mean by the tribe's mean proportion of shellfish harvested from Puget Sound[18] to yield percentiles and mean consumption of shellfish harvested from Puget Sound. This procedure seems reasonable, but how well does it work?

In order to assess the accuracy of these, simple, proportionality adjustments, we used consumption rates from the Tulalip Tribes, for which data were available at the individual level. The data could also be handled as if certain data were available only in published form as means, as was the case for the Squaxin Island Tribe and for some other populations covered in this report.

Using the Tulalip Tribes' individual level data, in this appendix we have calculated the mean and percentiles of consumption (g/day) for fish harvested from Puget Sound. We compare the results starting from two different types of data: a) consumers' individual level consumption rates of g/kg-day, individual body weight (kg) and individual stated percent harvested from Puget Sound; and, b) starting from consumer-only published percentiles and mean of consumption expressed in g/kg-day (from Polissar, 2006) and adjusting it to g/day harvested form Puget Sound using all-tribe group means for body weight and all-tribe group means for percent harvested from Puget sound[19]. We test the validity of the group "means" approach by applying it to the Tulalip Tribes' published consumer-only consumption rates in g/kg-day, and then compare the resulting mean and percentiles to the corresponding mean and percentiles calculated by fully using the individual level data.

Table A-3 shows the summary statistics that result from using the full Tulalip individual-level data vs. the summary statistics that result from using the "means" estimation method described above, starting from the consumer-only percentiles of fish consumption in g/kg/day from Polissar, 2006..

[18] Each adult survey respondent reported their own estimate of their percentage of consumed shellfish which was harvested from Puget Sound.
[19] The Tulalip Tribes' mean percent harvested from Puget Sound for all fish was calculated in the same way as the corresponding statistic for the Squaxin island Tribe. See Appendix 3, section on the Squaxin Island Tribe, for details and formulas.

Note that the agreement between the two methods is fair to good for the mean, median and for the 75th to the 90th percentile, but the agreement is poor for the 95th percentile. The sample size is only 73 individuals, so the agreement is likely to be better even at the 95th percentile for sufficiently large sample size.

Table A-3: mean, median and percentiles of fish consumption (g/day), all species, calculated from individual level data and calculated by using group means for body weight and for percent harvested form Puget Sound.

Method	mean	50%	75%	80%	85%	90%	95%
Using individual-level data	59.5	29.9	75	79.4	122.6	138.5	237.4
Using group means	48.8	29.3	53.7	68.3	92.7	117.1	126.9